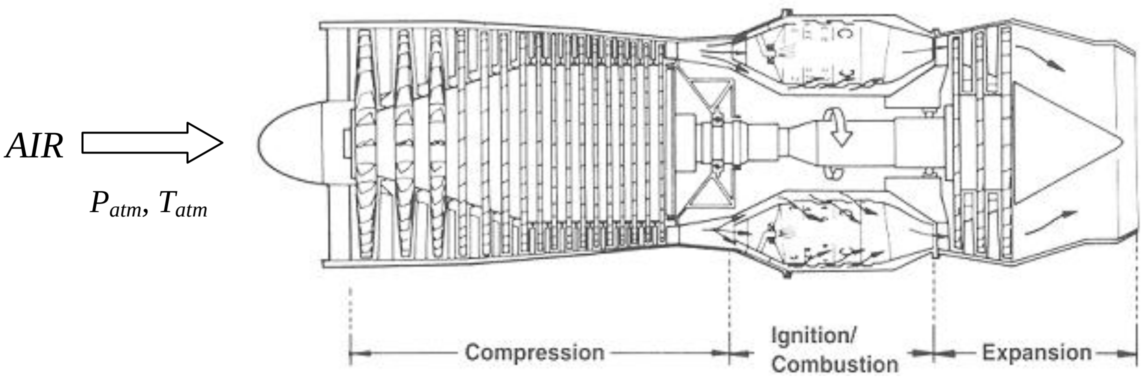
Homework #5: Specific Work in a Turbojet Engine

Due: Monday, April 29 by 4:00 PM (hard-copy & drop-box formats)

A **turbojet engine** is a gas turbine device designed specifically to generate thrust for aircraft propulsion. The following figure is a schematic of a single-spool turbojet, identifying the main components: a *compressor* stage which decelerates and compresses the incoming air; a *combustor* stage in which fuel is added and ignited, substantially increasing the enthalpy of the air-fuel mixture; and a *turbine* stage whose primary purpose is to extract enough energy through expansion to power the compressor.



Mounted on a stationary test rig, the distributions of pressure P and temperature T as tabulated and graphed below were measured for some prototypical engine; where each is given as a ratio to inlet (prevailing atmospheric) values P_{atm} and T_{atm}, respectively. It is reasonable to assume that the same relative distributions apply even during actual flight of the engine. With the data, we can calculate the *specific work w*, which follows under the assumption of internal reversibility and negligible kinetic and potential energy changes as:

$$\text{specific work } w = -\int v \cdot dP$$

Where v is the specific volume of the gas. Because the exact chemistry of air-fuel mixtures is very complicated, it is customary to treat the mixture properties as those of pure air, and to assume additionally that the air behaves as an ideal gas [$Pv = RT$, where R is the *gas constant* specific to air]. With the data and information given, submit **no more than two pages** in which you:

- Create a P-v diagram for the engine in actual flight at 40,000 ft, for which $P_{atm} \sim 18.75$ kPa and $T_{atm} \sim 217$ K.
- Calculate and plot the specific work for the compressor-combustor-turbine combination under the same conditions of flight; that is, based on the equation above, the negative area under the v vs. P curve is the specific work. Use trapezoidal-rule integration since the data taps are not evenly spaced along the engine long-axis.

Data follow below…

Relative Engine Position	***Pressure Ratio (P/P_{atm})***	***Temperature Ratio (T/T_{atm})***
0.000	1.0000	1.0000
0.013	1.0800	1.0222
0.025	1.1867	1.0501
0.038	1.3200	1.0826
0.051	1.4800	1.1185
0.063	1.6667	1.1571
0.076	1.8800	1.1977
0.089	2.1200	1.2395
0.101	2.3867	1.2822
0.114	2.6800	1.3253
0.127	3.0000	1.3687
0.139	3.3467	1.4122
0.152	3.7200	1.4555
0.165	4.1200	1.4986
0.177	4.5467	1.5414
0.190	5.0000	1.5838
0.203	5.4800	1.6258
0.215	5.9867	1.6675
0.228	6.5200	1.7086
0.241	7.0800	1.7493
0.253	7.6667	1.7896
0.266	8.2800	1.8293
0.278	8.9200	1.8687
0.291	9.5867	1.9076
0.304	10.2800	1.9460
0.316	11.0000	1.9840
0.329	11.7467	2.0216
0.342	12.5200	2.0587
0.354	13.3200	2.0955
0.367	14.1467	2.1319
0.380	15.0000	2.1678
0.392	15.8800	2.2034
0.405	16.7867	2.2387
0.418	17.7200	2.2735
0.430	18.6800	2.3081
0.443	19.6667	2.3423
0.456	20.6800	2.3761
0.468	21.7200	2.4097
0.481	22.7867	2.4429
0.494	23.8800	2.4758

Relative Engine Position	***Pressure Ratio (P/P_{atm})***	***Temperature Ratio (T/T_{atm})***
0.506	25.0000	2.5085
0.519	25.0000	2.5075
0.532	25.0000	2.5066
0.544	25.0000	2.5056
0.557	25.0000	2.5047
0.570	25.0000	2.5037
0.582	25.0000	2.5027
0.595	25.0000	2.6901
0.608	25.0000	2.8775
0.620	25.0000	3.0649
0.633	25.0000	3.2523
0.646	25.0000	3.4397
0.658	25.0000	3.6271
0.671	25.0000	3.8144
0.684	25.0000	4.0018
0.696	25.0000	4.1892
0.709	25.0000	4.3766
0.722	25.0000	4.5640
0.734	25.0000	4.7514
0.747	25.0000	4.9388
0.759	25.0000	5.1261
0.772	25.0000	5.3135
0.785	25.0000	5.5009
0.797	25.0000	5.6883
0.810	25.0000	5.8757
0.823	25.0000	6.0631
0.835	25.0000	6.2505
0.848	25.0000	6.4378
0.861	25.0000	6.6252
0.873	25.0000	6.8126
0.886	25.0000	7.0000
0.899	21.8889	6.8183
0.911	19.7778	6.6235
0.924	17.6667	6.4133
0.937	15.5556	6.1843
0.949	13.4444	5.9319
0.962	11.3333	5.6493
0.975	9.2222	5.3262
0.987	7.1111	4.9450
1.000	5.0000	4.4715